TENNESSEE VALLEY AUTHORITY

Resource Development
River Basin Operations
Water Resources

PCB STUDIES ON FISH FROM WATTS BAR, FORT LOUDOUN, TELLICO, AND MELTON HILL RESERVOIRS - 1988

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ERRATUM

All references in this document to Clinch River mile (CRM 21.0) are incorrect and should be CRM 24.0. This correction is important because CRM 21.0 is in the Melton Hill Dam tailwater area and CRM 24.0 is in the Melton Hill Reservoir forebay area.

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by

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The preparation of a report of this type requires the assistance and cooperation of many people too numerous to mention, but there are two individuals who provided substantial input. Larry O. Hill was responsible for laboratory analyses and provided the laboratory methods section of the report. Thomas A. McDonough conducted data analyses and provided valuable consultation on those analyses.

EXECUTIVE SUMMARY

PCB contamination in fish from several east Tennessee reservoirs has been the subject of study for several years. The two primary study objectives are to define the geographical boundaries where contamination in fish ceases to be a problem and to determine the temporal trend in PCB concentrations in fish from reservoirs where the geographical extent of contamination has been defined.

Trend studies on Fort Loudoun and Tellico Reservoirs in 1988 did not substantiate the decrease in PCB concentrations in channel catfish that had been observed in 1987. Concentrations remain sufficiently high to be of concern and the Public Health Advisory issued in April 1989 remains in effect. PCB concentrations in largemouth bass from Fort Loudoun in the sample area outside of Little River embayment (the known source area) continued to decrease as observed in previous years. These trend studies should be continued to determine whether concentrations decrease further in subsequent years.

Studies conducted on Watts Bar Reservoir in 1988 to examine the downstream extent of contamination found high PCB concentrations in channel catfish from throughout the reservoir. High PCB levels were also substantiated in striped bass/hybrids. PCB concentrations were relatively low in smallmouth buffalo, largemouth bass, and crappie. Sauger from Watts Bar were relatively high in the one composite sample, indicating a need for evaluation of that species. Subsequent studies should continue to better define PCB concentrations in sauger, channel catfish, and striped bass.

Channel catfish and largemouth bass were collected from Melton Hill Reservoir to validate results from samples collected as part of a screening study in 1987. The 1987 samples had sufficiently high concentrations of PCBs to warrant further investigation. Concentrations in fish collected in 1988 were lower than those observed in 1987.

PCB STUDIES ON FISH FROM WATTS BAR, FORT LOUDOUN, TELLICO, AND MELTON HILL RESERVOIRS - 1988

INTRODUCTION

The Tennessee Valley Authority (TVA) reservoirs that are the subject of this report have been under investigation for several years due to contamination with polychlorinated biphenyls (PCBs). These investigations are designed and conducted by a team of professionals from TVA, the Tennessee Department of Health and Environment (TDHE), the Tennessee Wildlife Resources Agency (TWRA), and the Oak Ridge National Laboratory (ORNL).

As a result of the contamination, TDHE has issued several public notices during recent years advising against consumption of certain species of fish from these water bodies. The study has two primary objectives: (1) define the geographical boundaries where contamination in fish ceases to be a problem and (2) determine the trend in PCB loading in fish from reservoirs where the contamination has been well defined.

The purpose of this document is to briefly describe results of PCB analysis of fish collected from these reservoirs in autumn 1988 and compare them to results for previous years. These results were shared with all members on the study team as soon as they were received from the analytical laboratory rather than waiting for this formal report. Therefore, decisions on updating existing advisories and selection of study design for autumn 1989 were made months this document was prepared.

METHODS

Detailed procedures have been provided in a previous report for this study (Dycus and Hickman 1988). Therefore, only a synopsis of methods follows.

Field Sampling and Handling

Table 1 lists sample locations for each reservoir, species collected at each location, number of individuals of each species, and laboratory responsible for analysis (TVA, TDHE, or ORNL). Immediately after collection fish were placed on ice and as soon as possible taken to the biological laboratory for processing where each fish was measured, weighed, and general condition noted. Fish were then filleted, sex determined, and examined for internal abnormalities. Skin was removed from catfish, while scales of other species were removed leaving the skin on the fillet. The belly flap was left on all fillets. Fillets were individually wrapped in aluminum foil and frozen for later analysis.

Laboratory

These procedures described below were followed by the TVA laboratory on samples identified in table 1. Procedures used by the other laboratories may have differed slightly. To evaluate differences among laboratories, the QA/QC program established for this study required each laboratory to provide aliquots of selected samples to the other laboratories for analysis. Details of this split-sample effort are described in appendix A.

Each fish tissue sample was partially thawed, diced with a knife, and thoroughly ground using a mechanical grinder. Compositing was

performed, as appropriate (table 1), by combining equal aliquots of tissue mass from each of the individually ground fillets. PCBs were extracted using petroleum ether and ultrasonication. An aliquot of the resulting extract was cleaned with concentrated sulfuric acid, and analyzed for PCBs (Aroclors 1016, 1221, 1232, 1242, 1246, 1254, and 1260) using a precalibrated gas chromatograph equipped with a capillary column, an electron detector, and an electronic integrator. Lipid content of all samples was determined gravimetrically.

Data Analysis

Statistical techniques used in evaluation of results included simple descriptive statistics, simple and partial correlations, analysis of variance, and analysis of covariance. Prior to statistical analyses, concentrations of PCBs were transformed to approximate a normal distribution using a $\log_{10}$ (x+1) transformation (x+1 was used because some values were between zero and one). Lipid content was transformed using arc sine. An alpha of 0.05 was chosen as the level of significance. Samples with less than detectable levels (0.1 µg/g) were included at the detection limit in developing averages.

Statistical tests were applied only to those data from the TVA laboratory. Tests based on temporal comparisons included only data from fish processed and analyzed with consistent protocols (i.e., since 1985).

RESULTS AND DISCUSSION

Fort Loudoun Reservoir

Fort Loudoun Reservoir is considered to be in the trend study stage. The PCB contamination is defined for most of the important fish species although additional species are examined each year if the study team deems necessary. The two species of primary concern are channel catfish (and other catfish as well) and largemouth bass. The Public Notice issued by TDHE advises against consumption of these species, and TWRA has banned commercial fishing for catfish in Fort Loudoun Reservoir. Two additional species (sauger and smallmouth buffalo) were to be examined in 1988, but neither of these species were encountered during collection efforts; hence, no data are available.

Because Fort Loudoun Reservoir is in the trend study stage, fish are no longer collected from throughout the reservoir. Only two areas continue to be sampled--Little River embayment (the area considered to be the primary source of PCBs) and an area in the main body of the reservoir at Tennessee River Mile (TRM) 628, a few miles downstream from the confluence of Little River with the Tennessee River. When fish from one or both of these areas are found to contain low concentrations of PCBs, the study area will be expanded to ensure acceptable levels exist throughout the reservoir.

Channel Catfish

Physical Characteristics. Catfish collected in the vicinity of Little River have historically been in poorer condition and had more

anomalies than those from other sections of the reservoir (Dycus 1989a). Such comparisons for the entire reservoir are not possible for 1988 because fish were collected only from two areas. Of the 20 channel catfish collected in 1988, 3 (all from TRM 628) had internal parasites and the remaining 17 were considered normal by the observer. These results parallel those for 1987 when 15 of 20 were normal, indicating that the condition of catfish in this section may be improving.

Sizes (length and weight) of catfish analyzed from 1988 are summarized in table 2 and detailed in appendix B. Catfish weight and lipid content did not differ significantly between the two sample locations in 1988 (table 3). Lipid content did not differ statistically among years (1985, 1987, and 1988) although fish weight did with larger fish collected in 1987 and 1988 than in 1985 (table 4).

PCB Concentrations. PCB concentrations in catfish collected in 1988 and in previous years are summarized in table 5 and details for 1988 are given in appendix B. Mean concentrations were 1.1 and 3.5 µg/g at TRM 628 and Little River, respectively in 1988. These results are closer to 1985 results than those for 1987.

A preliminary test was run to determine if there was a significant relation between PCB concentration and lipid content and/or fish size. This was used to determine if analysis of covariance was necessary. Preliminary tests were run on 1988 data alone to examine location differences (table 6) and then on data for 1985, 1987, and 1988 to examine year and location differences (tables 7 and 8). Results of preliminary tests indicated adjustment for neither lipid content nor fish size was necessary, hence, analysis of variance (ANOVA) was the appropriate test.

PCB concentrations were significantly higher at Little River than at TRM 628 in 1988 as shown by a one-way ANOVA and Duncan's Multiple Range Test (table 6). When data from all three years were tested with a two-way ANOVA, PCB concentrations were again significantly higher at Little River than at TRM 628 (table 7). A significant difference was not detected among years (table 7). Higher concentrations in catfish from Little River embayment were expected based on previous results for this reservoir.

Absence of significant differences among 1985, 1987, and 1988 is contrary to results of similar tests from the previous year when concentrations in 1987 were significantly lower than those in 1985 (Dycus 1989a). At the time that report was written, the lower levels in 1987 were interpreted as a indication that PCB concentrations in Fort Loudoun Reservoir catfish might be decreasing over time. The 1988 results contradict that interpretation.

Largemouth Bass

Physical Characteristics. External lesions and infections on largemouth bass collected in the vicinity of Little River have been a common observation in previous studies (1985-1987). Presence of these undesirable conditions was more pronounced in 1987 than in previous years: 40 percent of the largemouth bass from both sample sites had external lesions in 1987 compared to 10-20 percent in 1985 and 1986. Interestingly, this trend was not apparent for largemouth bass collected in 1988: only one of 20 had an external lesion and one had a deformed jaw. Hopefully, the 1988 observations on largemouth bass and channel

catfish signal a reverse of the previous trend of poor condition in this section of the reservoir.

Largemouth bass collected from Little River in both 1986 and 1987 were much larger than those from TRM 628 (table 9). Because weight of largemouth bass had been found to have an important influence on PCB concentration in previous years, individuals of comparable sizes were collected from the two locations in 1988. Average weight of largemouth bass was 1118 g at Little River and 1207 g at TRM 628. Weights were not significantly different between the two locations ($P>F = 0.3473$, table 3). Likewise, lipid content did not differ significantly between the two locations in 1988 ($P>F = 0.5586$, table 3). When tested with previous years in a two-way ANOVA, tests for both fish weight and lipid content had a significant interaction term, probably due to the explicit effort to collect large fish from TRM 628 in 1988, yet not in previous years (table 10). Fish size is usually an important factor in studies of this type, and its importance here cannot be overstated. Previous studies have shown that in areas outside of Little River embayment no largemouth bass under two pounds have ever been collected which exceed the FDA tolerance for PCBs of 2.0 µg/g.

PCB Concentrations. Average PCB concentrations were 1.7 µg/g for fish from Little River and 0.5 µg/g for fish from TRM 628 in 1988 compared to 2.5 and 0.3 µg/g in 1987, 2.6 and 1.0 µg/g in 1986, and 1.8 and 1.0 µg/g in 1985 (table 11). The procedure described above was also followed for largemouth bass data to determine if analysis of covariance was needed. The preliminary test on 1988 data alone found PCB concentrations were related to both lipid content and fish weight

indicating the need to use analysis of covariance (table 6). Test results on PCB levels adjusted for fish weight, as well as tests adjusted for lipid content, identified significantly higher PCB concentrations in largemouth bass from Little River than those from TRM 628 (table 6). Analysis of covariance was also needed in the two-way test to examine temporal and spatial differences because PCB concentrations exhibited a significant relationship with lipid content and with fish weight (table 7). Results from the two-way analysis of covariance found there were significantly higher PCB concentrations (adjusted for fish weight) at Little River than at TRM 628 (table 8). Test results also show a continued decline in PCB concentrations from year to year with lowest concentrations (adjusted for fish weight) in 1988. These results are encouraging and indicate the advisory not to consume large (those greater than 2 pounds) largemouth bass from areas outside of Little River embayment may need to be reevaluated and possibly lifted. The test was not run on data adjusted for lipid content because regression lines were not parallel at each location indicating lipid content affected PCB concentration at each location differently. The complex relationships between PCB concentration, lipid content, and fish weight in largemouth bass has been addressed in previous reports and will not be reexamined here (Dycus et al., 1987 and Dycus and Hickman, 1988). It is important that a concerted effort continue to be made to ensure collection of large largemouth bass at each location so the size bias can be dealt with.

Tellico Reservoir

Tellico Reservoir is also in the trend study stage. The PCB problem (in catfish only) was first documented in 1985 (Dycus and Hickman 1986). The problem was better defined in 1986 (Dycus and Hickman 1988) and the study continues to determine the year-to-year trend in PCB concentrations in catfish from lower and midreservoir areas at Little Tennessee River Miles (LTRM) 1 and 11, respectively.

Channel Catfish

Physical Characteristics. A high incidence of internal parasitism (larval tapeworms) has been observed in channel catfish during previous studies in 1985, 1986, and 1987. This observation continued to be evident and possibly even higher in 1988--infestation rate was 90 percent at LTRM 1 and 100 percent at LTRM 11. The only other anomaly observed was a mottled liver in one channel catfish from LTRM 11. Parasitism appears to occur at a greater frequency and at a more severe level in channel catfish from Tellico Reservoir than in those from other TVA reservoirs, even the adjacent Fort Loudoun Reservoir. These observations have been shared with TWRA and the situation will continue to be monitored in future studies.

Sizes (length and weight) of catfish analyzed in 1988 are summarized in table 12 and detailed in appendix A. Rather large fish were collected at both sites (average weight 1092 g at LTRM 1 and 1332 g at LTRM 11). There were no significant differences detected in fish weight or lipid content between the two locations in 1988 (table 13). When analyzed with data from previous years in a two-way analysis of

variance (location and year as the two main effects), only the difference in fish weight was significant with larger catfish collected in 1986 than in 1987 or 1988 (table 14). This could be an important consideration when comparing PCB concentrations between years because larger fish frequently have higher PCB concentrations than smaller fish.

PCB Concentrations. Average PCB concentrations in 1988 were 1.6 and 1.2 µg/g at LTRMs 1 and 11, respectively, compared to 0.9 and 1.0 µg/g in 1987 and 1.4 and 1.6 µg/g in 1986 (table 15). The same procedure followed for Fort Loudoun data was followed for Tellico where the need to adjust for lipid content and/or fish weight was evaluated to determine if covariance analysis was needed (table 16). The preliminary test on 1988 data alone showed adjustment was needed for lipid content but not fish weight. However, the test of parallel lines was violated (table 16) indicating lipid content affected PCB level differently at the two locations, thus making use of the covariance procedure inappropriate. Close examination of lipid contents at the two locations shows generally higher lipid levels at LTRM 1 than at LTRM 11--eight of the ten fish at LTRM 1 had more than 3 percent lipids whereas eight of the ten from LTRM 11 had less than 3 percent lipids (appendix B). This difference was likely responsible for violation of the test of parallel lines. As stated above, this difference in lipid content was not significant at the 0.05 level (the predetermined level of significance), but was at 0.0677 (table 13).

A similar procedure was followed for a two-way test (location and year) which also found adjustment was needed for lipid content but not fish weight (table 17). The two-way analysis of covariance failed to

detect a significant difference for the location effect, but the year effect was significant with lower PCB concentrations in 1987 than 1986 and 1988 (table 17). The lower concentrations in 1987 were viewed at the time as a hopeful indication of a downward trend in PCB concentrations in Tellico Reservoir. Unfortunately, this trend was not verified in these 1988 collections.

Watts Bar Reservoir

Watts Bar Reservoir is in the problem definition stage. Neither the geographical extent nor number of species contaminated with PCBs has been adequately defined. Previous collections from upper Watts Bar have identified substantial contamination in catfish and striped bass (Dycus and Hickman 1988). The length of the study reach has been expanded downstream each year since the tailwaters area of Fort Loudoun Dam was first included in 1985. The study plan for 1988 included the first collections of fish from the entire length of Watts Bar to examine the downstream extent of contamination. Channel catfish were collected from four locations between TRM 532 (near Watts Bar Dam) and TRM 598 (near Fort Loudoun Dam) and one location on the Clinch River (CRM 2) near its confluence with the Tennessee River. Individual striped bass from one location and smallmouth buffalo from two locations were analyzed to better define contamination levels. Composites of largemouth bass, crappie, and sauger were analyzed to determine if there was a potential problem with these important species (table 1). Catfish from another location on the Clinch River at mile 19 (near Melton Hill Dam) were

collected and analyzed by the ORNL and are reported here but were not included in statistical analyses.

Channel Catfish

Physical Characteristics. Previous observations on channel catfish from upper Watts Bar Reservoir had not found any external anomalies, although internal parasites were observed in about 30 percent of the catfish. A similar situation (about 30 percent infestation) was observed in 1988 in catfish from the upper Watts Bar. A much higher occurrence (90 percent) of internal parasites was found in catfish from the forebay area (TRM 532), which had not sampled previously.

Sizes (length and weight) and lipid content of catfish analyzed from 1988 are summarized in table 18 and detailed in appendix B. Neither fish weight nor lipid content differed significantly among sample sites in 1988 (table 19).

PCB Concentrations. PCB concentrations in catfish collected in 1988 and previous years are summarized in table 18 with specific information for 1988 provided in appendix B. The initial examination of PCB concentrations in channel catfish from immediately downstream of Fort Loudoun Dam (TRM 602) in 1985 found an average of 1.4 µg/g and a maximum of 2.0 µg/g (table 18). Subsequent collections in 1986 found an average of 2.1 µg/g and a maximum of 3.5 µg/g in channel catfish from TRM 602 and an average of 3.6 µg/g and maximum of 4.3 µg/g a few miles downstream at TRM 598 (table 18). The 1986 results also identified a statistically significant lower PCB concentration in blue catfish than in channel catfish (Dycus and Hickman 1988). Since that time, efforts

have been made to specifically collect channel catfish. In 1987 the study area was extended about 30 miles downstream to the midreservoir area; mean PCB concentrations in channel catfish were 1.4, 2.1, 2.2, and 1.5 µg/g at TRMs 565, 573, 585, and 598 with maxima of 4.4, 3.0, 3.2, and 3.1 µg/g, respectively (Dycus 1989a).

In 1988 PCB concentrations averaged 1.4, 2.7, 2.1, and 2.4 µg/g at TRMs 532, 565, 573, and 598 with maxima of 4.3, 7.5, 7.4, and 4.4, respectively. The two sites on the Clinch River averaged 2.2 and 0.6 µg/g at Clinch River miles (CRM) 2 and 19, respectively with maxima of 4.6 and 2.4 µg/g (table 18). Statistical examination of the 1988 results was based on a one-way analysis of covariance to adjust for lipid content and fish weight. The test based on PCB concentrations adjusted for lipid content did not identify a significant difference among collection sites (table 20). However, the test adjusting PCB concentrations for fish weight found a significantly lower level at TRM 532 than at the other sample locations on the Tennessee River (table 20). Although there is this indication of lower PCB concentration in catfish from the downstream end of Watts Bar Reservoir, concentrations are sufficiently high throughout the reservoir to have implications for human health if these fish are consumed in quantity.

Year to year differences were not tested statistically because of inconsistencies in availability of data for each location due to expansion of the study area from 1985 to 1988.

Striped Bass and Hybrids

Physical Characteristics. None of the 10 striped bass had notable external or internal anomalies. Weights ranged from 905 to 7135 g (appendix B).

PCB Concentrations. Four striped bass were collected in 1986 from TRM 600 and found to have PCB concentrations ranging from 1.5 to 5.7 µg/g (Dycus and Hickman 1988). In 1987 striped bass and striped bass/white bass hybrids from TRM 573 ranged 1.4 to 4.8 µg/g whereas striped bass from TRM 598 ranged 0.3 to 4.8 µg/g with average PCB concentrations of 2.9 and 1.5 µg/g, respectively (Dycus 1989a). In 1988 PCB concentrations in striped bass from the lower reservoir area (TRM 532) ranged 0.2 to 4.8 µg/g with an average of 2.0 µg/g (appendix B).

Smallmouth Buffalo

Physical Characteristics. All 10 individuals from TRM 570 were healthy with no noteworthy anomalies. Only one of the desired 10 smallmouth buffalo was collected from TRM 532 and it appeared healthy.

PCB Concentrations. The 1987 study included a five-fish composite of smallmouth buffalo from TRM 573. The PCB concentration in that sample was 3.1 µg/g. In 1988 the single smallmouth buffalo from TRM 532 had a PCB concentration of 0.4 µg/g and the 10 from TRM 570 (same general collection area as the previous year) ranged from 0.2 to 1.4 µg/g and averaged 0.8 µg/g (appendix B). These concentrations are substantially lower than that observed in the 1987 composite. This difference may be due in part to the mobility of this species. The individuals collected

in 1988 may have been in some less contaminated area of Watts Bar Reservoir than those collected in 1987. Subsequent collections should shed more light on contamination levels in this species.

Other Species

Physical Characteristics. There were 20 largemouth bass, 10 crappie, and 5 sauger collected from Watts Bar in 1988 (the 5 sauger were not collected as planned from TRM 598). Of these, two largemouth bass had an unusual growth in the viscera, one largemouth bass had internal parasites, one crappie had a mottled liver, and one sauger had fin rot. The growths in the viscera of the two largemouth bass are of interest and bear need for further investigation. The more detailed Fish Health Condition Assessment conducted on this species in 1989 did not identify a significant problem with this type anomaly in largemouth bass examined from Watts Bar Reservoir (Brown and Hickman, Draft).

PCB Concentrations. Relatively low PCB concentrations were found in these species, except sauger. The four largemouth bass composites ranged between 0.1 and 0.6 µg/g (appendix B), compared to a range of 0.3 to 1.4 µg/g in three composites in 1987. Both crappie composites had less than detectable concentrations of PCBs in 1988 compared to a maximum of 0.6 µg/g in 1987. The sauger composite from CRM 2 had 1.7 µg/g in 1988. Sauger had previously been analyzed only from the Fort Loudoun Dam tailwaters area of Watts Bar Reservoir in 1986 and the 10 sauger analyzed individually had a maximum of 0.6 µg/g and an average of 0.4 µg/g (Dycus and Hickman 1988). These results indicate PCB concentrations in sauger need further evaluation.

Melton Hill Reservoir

Melton Hill Reservoir is in the problem definition stage. Results from the Valley-wide Fish Tissue Screening Study in 1987 found sufficiently high concentrations of PCBs and chlordane to warrant more indepth examination (Dycus 1989b). The screening study included two five-fish fillet composites, one each from lower and mid reservoir areas (CRMs 20 and 39). These contained 1.2 and 2.0 µg/g PCBs, respectively and 0.16 µg/g chlordane each. The study team decided to analyze 8 channel catfish (individually) from lower (CRM 21), mid (CRM 39), and upper (CRM 50) reservoir areas (table 1). A five-fillet composite of largemouth bass was also analyzed from the mid and upper reservoir areas. ORNL collected, processed, and analyzed catfish from the lower reservoir area, whereas fish from the mid and upper areas were collected by TWRA, processed by TVA, and analyzed by TDHE.

Channel Catfish

Physical Characteristics. Observations on catfish from the mid and upper reservoir areas (this information was not available from the lower area) indicated 15 of the 16 were normal. The only noted observation was external parasites on one catfish. Channel catfish from all three areas were large--average weights 1774, 2640, and 1597 g at the lower, mid, and upper areas; appendix B. Lipid content was lower than expected given the size of the fish sampled (average 3.8, 2.1, and 2.2 percent at lower, mid, and, upper areas, respectively).

PCB Concentrations. PCB data are not available for all eight channel catfish from the mid and upper reservoir areas because the TDHE

laboratory experienced technical problems with those samples. However, the split-sample QC effort included one channel catfish and an aliquot from the largemouth bass composite from each of these two areas to be analyzed by the TVA and ORNL laboratories Thus, complete data are available only from the lower reservoir area.

The eight channel catfish from the lower reservoir area had an average PCB concentration of 0.52 µg/g and a range of 0.10 to 1.6 µg/g (appendix B). The single catfish from the mid reservoir area had 2.0 µg/g based on the TVA laboratory analysis and 2.6 µg/g based on the ORNL analysis (appendix A). The catfish from the upper reservoir area had 2.2 µg/g based on TVA's analysis (ORNL results are not available because the sample container was broken during processing).

Largemouth Bass

Physical Characteristics. No noteworthy observations were made on the 10 largemouth bass. Fish weights ranged 553 to 1489 g (average 883 g) at the midreservoir area and 569 to 1151 g (average 815 g) at the upper area (appendix B). Lipid content was relatively low--0.11 and 0.50 percent in composites from the mid and upper areas respectively.

PCB Concentrations. Both the TVA and ORNL laboratories reported a concentration of 0.7 µg/g in the largemouth bass composite from the midreservoir area, whereas the TVA lab reported <0.1 µg/g and ORNL reported 0.12 µg/g in the composite from the upper area (appendix A).

RECOMMENDATIONS

The study design for autumn 1989 collections is shown in table 21.

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TABLES

Table 1. Summary of Study Design (Species, Collection Sites, and Individual versus Composite Analyses) for Fish Tissue Studies in Autumn 1988 on TVA Reservoirs in Vicinity of Knoxville, Tennessee

Reservoir site[a]	Channel catfish	Largemouth bass	Striped bass/ hybrids	Smallmouth buffalo	Walleye	Sauger	Crappie
Fort Loudoun							
Little River	10-I[b]	10-I	-	-	-	-	-
TRM 628	10-I	10-I	-	-	-	-	-
Forks of River	-	-	-	5-C[c]	-	5-C	-
Tellico							
LTRM 1	10-I	-	-	-	5-C	-	-
LTRM 11	10-I	-	-	-	5-C	-	-
Watts Bar							
TRM 532	10-I	5-C	10-I	10-I	-	-	5-C
TRM 562	10-I	-	-	-	-	-	-
TRM 572	10-I	5-C	-	10-I	-	-	5-C
TRM 598	10-I	5-C	-	-	-	5-C	-
CRM 2	8-I	5-C	-	-	-	5-C	-
CRM 19[d]	8-I	-	-	-	-	-	-
Melton Hill							
CRM 21[d]	8-I	-	-	-	-	-	-
CRM 39[e]	8-I	5-C	-	-	-	-	-
CRM 50[e]	8-I	5-C	-	-	-	-	-

a. TRM = Tennessee River mile; LTRM = Little Tennessee River mile; CRM = Clinch River mile.
b. I = Analysis of 10 individual fish.
c. C = Analysis of one composite sample composed of five fish.
d. Samples collected and analyzed by Oak Ridge National Laboratory as part of a separate study.
e. Samples analyzed by State of Tennessee Laboratory.

NOTE: All other samples analyzed by Tennessee Valley Authority Laboratory. Samples from Clinch River sites were included in a split sample, interlaboratory quality assurance program (appendix A).

Table 2. Minimum, Maximum, and Mean Lengths and Weights of Channel Catfish Collected from Fort Loudoun Reservoir, 1981, 1985, 1987, and 1988

		Length (mm)			Weight (g)		
Location	Year	Minimum	Maximum	Mean	Minimum	Maximum	Mean
TRM 604	1981[a]	457	584	508	1020	2948	1678
	1985	346	526	447	370	1480	848
	1987	NS[b]	NS	NS	NS	NS	NS
	1988	NS	NS	NS	NS	NS	NS
TRM 617	1981	NS	NS	NS	NS	NS	NS
	1985[c]	351	560	456	382	1600	892
	1987	NS	NS	NS	NS	NS	NS
	1988	NS	NS	NS	NS	NS	NS
TRM 628	1981[a,c]	483	610	549	1587	2948	2313
	1985[c]	330	655	441	270	2720	834
	1987	410	645	507	580	2275	1385
	1988	391	577	466	538	1732	968
Little River	1981	330	584	424	255	1587	759
	1985	295	585	386	176	2230	533
	1987	375	562	454	426	2294	1072
	1988	420	606	987	948	2493	1637
TRM 638	1981	NS	NS	NS	NS	NS	NS
	1985	309	561	421	219	1740	658
	1987	NS	NS	NS	NS	NS	NS
	1988	NS	NS	NS	NS	NS	NS
TRM 643	1981[a,c]	432	533	483	680	2154	1338
	1985[c]	356	632	446	380	2250	821
	1987	NS	NS	NS	NS	NS	NS
	1988	NS	NS	NS	NS	NS	NS
TRM 651	1981	381	508	437	623	1417	884
	1985	362	465	414	347	1010	656
	1987	NS	NS	NS	NS	NS	NS
	1988	NS	NS	NS	NS	NS	NS

a. Some individuals were flathead catfish.
b. NS = Not sampled.
c. Some individuals were blue catfish.

Table 3. Results of One-Way ANOVA on Location Differences of Fish Weight and Lipid Content for Channel Catfish and Largemouth Bass from Fort Loudoun Reservoir in 1988

Species	Parameter	P>F
Channel catfish	Weight	0.0605
	Lipid content	0.9281
Largemouth bass	Weight	0.3473
	Lipid content	0.5586

Table 4. Two-Way Analysis of Variance and Duncan's Multiple Range Test on Lipid Content and Total Weight in Channel Catfish from Fort Loudoun Reservoir, 1985, 1987, and 1988 (Location and Year Main Effects)

		P>F	Duncan's Multiple Range Test[a] Mean Rank Low to High
Lipid content	Location	0.9170	
	Year	0.0663	
	Interaction	0.6287	
Total weight	Location	0.6036	
	Year	0.0019	1985 1987 1988
	Interaction	0.0670	

a. Locations or years underscored by same line were not significantly different at $\alpha = 0.05$. Years not so underscored were significantly different.

Table 5. Summary of Total[a] PCB Concentrations (µg/g Wet Weight) in Individual Catfish Fillets from Fort Loudoun Reservoir, Collected in Spring 1981 and Fall of 1985, 1987, and 1988

	TRM[b] 604	TRM 617	TRM 628[c]	Little River	TRM 638	TRM 643	TRM 651
1981							
Range	1.5–5.8	d	2.3–7.2	<1.0–22	d	<1.0–1.6	<1.0–4.4
Mean[e]	3.5		4.5	6.6		1.4	2.1
Number ≥2.0 µg/g	4		5	62		0	1
Number of fish	5		5	64[f]		5	5
1985							
Range	<0.1–2.9	0.18–2.4	0.16–2.8	1.3–9.3	<0.1–4.9	<1.0–1.1	<0.1–1.0
Mean	1.7	1.2	1.4	4.4	1.3	0.75	0.62
Number ≥2.0 µg/g	3	3	2	7	2	0	0
Number of fish	10	10	10	10	10	10	10
1987							
Range	d	d	0.1–4.5	0.2–5.3	d	d	d
Mean			2.2	2.4			
Number ≥2.0 µg/g			2	5			
Number of fish			10	10			
1988							
Range	d	d	0.2–4.4	1.8–7.1	d	d	d
Mean			1.1	3.5			
Number ≥2.0 µg/g			1	8			
Number of fish			10	10			

a. Sum of individual aroclors which occurred in concentrations greater than or equal to the detection limit of 1 µg/g in 1981 and 0.1 µg/g in 1985.

b. TRM = Tennessee River mile.

c. Additional catfish were collected in 1982 but not reported here.

d. Fish were not collected from this location.

e. Total PCB concentration less than detection limit (1 µg/g in 1981 and 0.1 µg/g in 1985) were averaged as the detection limit.

f. Four of these specimens were collected in spring 1981 at the same time as specimens from the other locations. The remaining 60 were collected in December 1981.

Table 6. Results of Statistical Tests Used To Compare PCB Concentrations in Channel Catfish and Largemouth Bass from the Two Sample Locations on Fort Loudoun Reservoir in 1988

Species	Parameter	Preliminary test results (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If ANOVA used (P>F)	If covariance used (test of parallel line)	Covariance results (P>F)
Channel catfish	Lipid content	No	Use ANOVA	0.0003[a]	N/A	N/A
	Weight	No	Use ANOVA	0.0003	N/A	N/A
Largemouth bass	Lipid content	Yes	Use covariance	N/A	Lines parallel; use of covariance appropriate	0.0001[b]
	Weight	Yes	Use covariance	N/A	Lines parallel; use of covariance appropriate	0.0001[b]

a. Results of Duncan's Multiple Range Test showed significantly higher PCB concentrations in catfish from Little River embayment than in catfish from TRM 628.

b. Mean PCB concentration (adjusted for lipid content or weight) was significantly higher at Little River than at TRM 628.

Table 7. Decision Path Followed in Determining Appropriate Statistical Test of Significance (Analyses of Variance or Analysis of Covariance) To Examine Temporal (Among Years) and Spatial (Among Locations) Differences in PCB Concentrations in Channel Catfish and Largemouth Bass from Fort Loudoun Reservoir, 1985, 1986, 1987, and 1988

Species	Parameter	Preliminary test[a]	Decision based on preliminary test	If (ANOVA) used (P<F)	
Channel catfish	Lipid content	Not significant	Ajustment not needed; use ANOVA	Location	0.001[b]
				Year	0.2037
				Interaction	0.2181
	Weight	Not significant	Adjustment not needed		
			use ANOVA		
Largemouth bass	Lipid content	Significant	Must adjust PCB concentrations for both lipid content and weight, achieved by use of analysis of covariance (see table 8)	N/A	
	Weight	Significant	See above	N/A	

a. Used to determine whether there is a significant relationship between PCB concentration and parameter (lipid and/or weight) for each test group (location and year).

b. Results of Duncan's Multiple Range Test showed PCB concentrations were significantly higher in catish from Little River embayment than those from TRM 628.

Table 8. Results of Two-Way Analysis of Covariance (Location and Year Main Effects) on PCB Concentrations in Channel Catfish and Largemouth Bass from Fort Loudoun Reservoir, 1985, 1986, 1987, and 1988

Species	Test of parallel lines[a]		Analysis of covariance test results	
	Lipid adjustment	Weight adjustment	Location	Year
Channel catfish	N/A	N/A	N/A	N/A
Largemouth bass	Lines not parallel	Lines parallel	P>F = 0.0001[b] TRM 628<LRM 3[b]	P>F = 0.0018[b] 1988 1987 1986 1985

a. Used to determine whether parameter (lipid and/or weight) has the same influence on PCB concentration for each test group (location and year). If slopes of regression lines for each test group are significantly different, analysis of covariance should not be used.

b. Based on adjustments for fish weight; test based on adjustments for lipid not run.

Table 9. Minimum, Maximum, and Mean Lengths and Weights of Large-Mouth Bass Collected from Fort Loudoun Reservoir, 1985, 1986, 1987, and 1988

		Length (mm)			Weight (g)		
Location	Year	Minimum	Maximum	Mean	Minimum	Maximum	Mean
TRM 617	1985	284	455	378	338	1710	954
	1986	284	526	407	322	2310	1181
	1987	NS[a]	NS	NS	NS	NS	NS
	1988	NS	NS	NS	NS	NS	NS
TRM 628	1985	282	466	331	334	1900	652
	1986	275	451	365	290	1400	793
	1987	280	491	323	296	2156	591
	1988	361	480	403	832	2054	1207
Little River	1985	236	494	342	168	2042	687
	1986	364	534	443	770	2920	1528
	1987	316	489	414	514	2080	1284
	1988	311	535	394	391	2941	1118
TRM 643	1985	293	523	418	220	2575	1322
	1986	317	520	377	440	2760	946
	1987	NS	NS	NS	NS	NS	NS
	1988	NS	NS	NS	NS	NS	NS

a. NS = Not sampled.

Table 10. Two-Way Analysis of Variance and Duncan's Multiple Range Test on Lipid Content and Total Weight in Largemouth Bass from Fort Loudoun Reservoir, 1985, 1986, 1987, and 1988 (Location and Year Main Effects)

		P>F	Duncan's Multiple Range Test[a] Mean Rank Low to High
Lipid content	Location	0.1525	
	Year	0.0449	
	Interaction	0.0004	
Total weight	Location	0.0092	
	Year	0.0248	
	Interaction	0.0451	

a. Duncan's Multiple Range Test not run because interaction terms were significant.

Table 11. Summary of Total[a] PCB Concentrations (µg/g Wet Weight) in Individual Largemouth Bass from Fort Loudoun Reservoir, Collected in Spring 1981 and Fall of 1985, 1986, 1987, and 1988

	TRM[b] 604	TRM 617	TRM 628[c]	Little River	TRM 638	TRM 643	TRM 651[c]
1981							
Range	1.0–1.1	d	<1.0	<1.0–2.0	d	d	<1.0–1.4
Mean[e]	1.0		1.0	1.4			1.1
Number ≥2.0 µg/g	0		0	2			0
Number of fish	5		2	8			5
1985							
Range	<0.1–0.84	0.11–4.0	0.23–3.2	0.59–4.5	<0.1–1.4	0.41–3.6	<1.0–2.3
Mean	0.36	1.4	1.0	1.8	0.47	1.6	0.6
Number ≥2.0 µg/g	0	3	1	3	0	3	1
Number of fish	10	10	10	10	10	10	10
1986							
Range	f	<0.1–2.2	<0.1–2.7	<0.1–7.1	f	<0.1–1.7	g
Mean		0.5	1.0	2.6		0.4	
Number ≥2.0 µg/g		1	2	5		0	
Number of fish		10	10	10		10	
1987							
Range	d	d	<0.1–1.3	<0.1–6.1	d	d	d
Mean			0.3	2.5			
Number ≥2.0 µg/g			0	5			
Number of fish			10	10			
1988							
Range	d	d	<0.1–1.0	0.2–4.8	d	d	d
Mean			0.5	1.7			
Number ≥2.0 µg/g			0	3			
Number of fish			10	10			

a. Sum of individual aroclors which occurred in concentrations greater than or equal to the detection limit of 1 µg/g in 1981 and 0.1 µg/g in 1985 and 1986.
b. TRM = Tennessee River mile.
c. Some individuals were spotted bass.
d. Fish were not collected from this location.
e. Total PCB concentration less than detection limit (1 µg/g in 1981 and 0.1 µg/g in 1985) were averaged as the detection limit.
f. Fish were collected from this location in 1986 but not analyzed.
g. No largemouth bass could be collected from this location in 1986.

Table 12. Minimum, Maximum, and Mean Lengths and Weights of Catfish[a] Collected from Tellico Reservoir, 1985, 1986, 1987, and 1988

		Length (mm)			Weight (g)		
Location	Year	Minimum	Maximum	Mean	Minimum	Maximum	Mean
LTRM 1.0	1985	NS[a]	NS	NS	NS	NS	NS
	1986	365	656	495	444	3750	1600
	1987	376	666	467	451	2902	1110
	1988	396	611	468	452	2481	1092
LTRM 10-11.5	1985	334	808	435	328	6200	1008
	1986	359	710	534	330	3650	1877
	1987	340	490	395	331	1075	551
	1988	390	627	509	570	2610	1332
LTRM 23-24	1985	455	700	581	710	3540	2225
	1986	433	625	498	586	2401	1112
	1987	NS	NS	NS	NS	NS	NS
	1988	NS	NS	NS	NS	NS	NS
TelRM 3-5	1985	305	552	385	204	2010	546
	1986	360	595	481	320	2120	1076
	1987	NS	NS	NS	NS	NS	NS
	1988	NS	NS	NS	NS	NS	NS

a. All individuals were channel catfish except four of the ten at LTRM 1.0 in 1986 were blue catfish. Data for both species were combined for this location.

b. NS = Not sampled.

Table 13. Results of One-Way ANOVA on Location Difference of Fish Weight and Lipid Content for Channel Catfish from Tellico Reservoir in 1988

Parameter	P>F	Duncan's Multiple Range Test[a] Mean Rank Low to High
Total weight	0.3002	-
Lipid content	0.0677	-

a. Duncan's Multiple Range Test not run because interaction terms were significant.

Table 14. Two-Way Analysis of Variance and Duncan's Multiple Range Test on Lipid Content and Total Weight in Catfish from Tellico Reservoir, 1986, 1987, and 1988 (Location and Year Main Effects)

		P>F	Duncan's Multiple Range Test[a] Mean Rank Low to High
Lipid content	Location	0.2295	-
	Year	0.1351	-
	Interaction	0.0968	
Total weight	Location	0.9470	-
	Year	0.0042	1987 1988 1986
	Interaction	0.2057	

a. Locations or years underscored by same line were not significantly different at $\alpha = 0.05$. Years not so underscored were significantly different.

Table 15. Summary of Total[a] PCB Concentrations in Catfish Fillets (Composites in 1985 and Individuals in 1986) Collected from Tellico Reservoir in Autumn 1985, 1986, 1987, and 1988

	LTRM[b] 1.0	LTRM 10–11.5	LTRM 16–18	LTRM[b] 23–24	TelRM 3–6
1985					
Range	c	1.0–3.2	1.2–2.6	1.4–1.9	0.67–1.8
Mean[e]		2.3	2.0	1.7	1.3
Number ≥2.0 µg/g		2	2	0	0
Number of fish		3–C[d]	3–C	3–C	3–C
1986					
Range	0.2–3.4	0.4–4.2	<0.1–1.2	<0.1–2.6	<0.1–1.8
Mean	1.4	1.6	0.34	0.83	0.47
Number ≥2.0 µg/g	2	2	0	1	0
Number of fish	10–1[f]	10–1	10–1	10–1	10–1
1987					
Range	<0.1–2.9	<0.2–2.2	c	c	c
Mean	0.9	1.0			
Number ≥2.0 µg/g	2	1			
Number of fish	10–1	10			
1988					
Range	0.3–4.2	072–2.2	c	c	c
Mean	1.6	1.2			
Number ≥2.0 µg/g	3	2			
Number of fish	10	10			

a. Sum of individual aroclors which occurred in concentrations greater than or equal to the detection limit of 1 µg/g.
b. TRM = Tennessee River mile; TelRM = Tellico River mile.
c. Fish were not collected from this location.
d. Three composites of five fish each were analyzed from each location.
e. Total PCB concentration less than detection limit were averaged as the detection limit.
f. Ten catfish were analyzed individually from each location; all were channel catfish except four individuals at Little Tennessee River mile 1.

Table 16. Results of Statistical Tests Used To Compare PCB Concentrations in Channel Catfish from the Two Sample Locations on Tellico Reservoir in 1988

Parameter	Preliminary test results (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If ANOVA used (P>F)	If covariance used (test of parallel line)	Covariance results (P>F)
Lipid content	Yes	Use covariance	-	Lines not parallel, use of covariance inappropriate	-
Fish weight	No	Use covariance because of need to adjust for lipid content	-		-

Table 17. Decision Path Followed and Results of Two-Way Testing (Location and Year) by Analysis of Variance or Analysis of Covariance for PCB Concentrations in Channel Catfish from Tellico Reservoir in 1986, 1987, and 1988

Parameter	Preliminary test results (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If covariance used (test of parallel line)	Analysis of covariance	
				Location	Year
Lipid content	Yes	Adjust PCB concentration for lipid content by use of analysis of covariance	Lines parallel	P>F=0.2216	0.0015 1987 1986 1988
Weight	No	No need to adjust PCB concentration for weight; but need to use analysis of covariance because of relationship to lipid content	-	-	-

Table 18. Summary (Minimum, Maximum, and Mean) for Lengths, Weights, Lipid Contents, and PCB Concentrations in Catfish from Watts Bar and Melton Hill Reservoirs During Each Year of Study

Location	Year	Species[a]	N[b]	Length (mm)			Weight (g)			Lipid content (%)			PCBs µg/g		
				Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Watts Bar															
TRM 532	1988	CHC	10	398	706	531	494	4210	1763	0.7	16.0	4.6	<0.1	4.3	1.4
TRM 565	1987	CHC	6	310	561	470	239	1786	1103	1.4	3.8	2.5	0.1	4.4	1.4
TRM 565	1988	CHC	10	390	657	492	411	2765	1124	0.9	13.0	5.5	1.3	7.5	2.7
TRM 573	1987	CHC	10	436	640	492	806	2814	1225	1.5	8.3	4.9	0.9	3.0	2.1
TRM 573	1988	CHC	10	346	615	450	264	2425	929	0.2	7.6	3.7	0.1	7.4	2.1
TRM 585	1987	CHC	5	383	556	460	327	1566	860	2.0	7.2	5.3	0.4	3.2	2.2
		BLC	5	445	535	480	718	1327	941	1.1	7.7	3.9	0.3	1.4	1.1
	1988	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TRM 598	1986	CHC	3	360	523	457	336	1330	757	3.3	7.3	5.3	2.9	4.3	3.6
		BLC	1	411	411	-	555	555	-	1.2	1.2	-	0.6	0.6	-
	1987	CHC	10	395	609	477	521	2578	1098	1.9	10.0	4.6	0.4	3.1	1.5
	1988	CHC	10	452	659	504	829	2957	1289	2.1	8.5	5.2	0.8	4.4	2.4
TRM 602	1985	CHC	10	383	546	430	430	1860	771	6.0	12.7	8.8	0.2	2.0	1.4
	1986	CHC	7	356	493	446	400	1300	829	1.9	6.4	4.4	0.9	3.4	2.1
		BLC	3	327	474	415	365	890	557	0.9	1.4	1.1	0.3	0.8	0.5
	1987	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1988	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CRM 2.0	1988	CHC	8	435	605	510	745	2262	1278	<0.1	11.0	5.3	<0.1	4.6	2.2
CRM 19	1988	CHC	8	309	495	407	340	1242	660	2.2	5.7	3.5	0.2	2.4	0.6
Melton Hill															
CRM 21	1988	CHC	10	370	790	513	406	6118	1774	1.0	11.5	3.8	<0.1	1.6	0.5
CRM 39[c]	1988	CHC	8	553	690	620	1748	3906	2630	-	-	-	-	-	-
CRM 50 [c]	1988	CHC	8	462	640	531	1010	3470	1587	-	-	-	-	-	-

a. CHC = channel catfish; BLC = blue catfish

b. N = number of fish

c. Tissue information available for only one fish at each site due to technical problems in the laboratory; see pages 16 and 17 for further explanation and table A-4 (page 48) for PCB and lipid data.

Table 19. Results of One-Way Analyses of Variance on Channel Catfish Weight and Lipid Content Among Sample Sites on Watts Bar Reservoir in 1988

	P>F
Lipid Content	0.5912
Weight	0.1990

Table 20. Results of Statistical Tests Used To Compare PCB Concentrations in Channel Catfish Among Sample Locations on Watts Bar Reservoir, 1988

Parameter	Preliminary test results (Is there a significant relationship between PCB concentration and parameter?)	Decision based on preliminary test	If ANOVA used (P>F)	If covariance used (test of parallel line)	Covariance results (P>F)
Lipid content	Yes	Adjust PCB concentration for lipid content and weight using analysis of covariance.	N/A	Lines parallel	P>F=0.2045
Fish weight	Yes		N/A	Lines parallel	P>F=0.0231 (TRM CRM TRM TRM TRM) 532 2 598 570 562

Table 21. Fish Collection Locations for the Knoxville Area Study, Autumn 1989

Reservoir	Location[a]	Species	Number
Chilhowee	Anywhere	trout	1C[b]
		carp	1C
Tellico	LTRM 1	channel cat	10
	LTRM 11	channel cat	10
Fort Loudoun	TRM 628	channel cat	20
		largemouth bass	10
	LRM 3	channel cat	20
	Anywhere	sauger	1C
Douglas	Tailrace	cat	1C
Watts Bar	CRM 2	sauger	10
	TRM 532	striped bass	10
	TRM 600	channel cat	10[c]
		sauger	10

a. This list does not include sites sampled by ORNL.

b. One five-fish composite.

c. Analyze for PCBs and chlordane.

APPENDIXES

APPENDIX A

RESULTS OF INTERLABORATORY QUALITY ASSURANCE PROGRAM FOR KNOXVILLE-AREA PCB STUDY

APPENDIX A

RESULTS OF INTERLABORATORY QUALITY ASSURANCE PROGRAM FOR KNOXVILLE-AREA PCB STUDY

The interagency study team for this project includes the Tennessee Valley Authority (TVA), the Tennessee Department of Health and Environment (TDHE), the Tennessee Wildlife Resources Agency (TWRA), and the Oak Ridge National Laboratory (ORNL). These agencies coordinate activities to maximize available manpower and financial resources.

In establishing the study plan for fish collections in autumn 1988, the study team decided to spread the laboratory analytical effort among laboratories in TVA, TDHE, and ORNL. This necessitated splitting a subset of samples among the laboratories to evaluate differences potentially introduced by the multiple laboratory analysis scheme.

An interlaboratory quality assurance program was developed and implemented to assess the validity of the data. Each laboratory prepared three additional 25-g tissue aliquots during grinding and dispensing manipulations. These samples were submitted to the other participating laboratories for analysis of total PCBs, chlordane, and percent lipids. Type of tissue, sample location, and originating laboratory are listed in table A-1.

Analytical results from each laboratory are provided in tables A-2, A-3, and A-4. Due to technical problems, data from the TDHE laboratory are not available for any of these analyses. The ORNL analyses of PCBs provided an average of 1.13 +/- 0.34 µg/g (standard error), whereas the TVA laboratory found 1.25 +/- 0.39 µg/g. Statistical analyses

conducted by ORNL personnel did not detect a significant difference between these data sets (ORNL, 1990). Tissue aliquots analyzed for chlordane averaged 0.034 +/- 0.012 µg/g by ORNL and 0.19 +/- 0.05 µg/g by TVA. These data sets were significantly different. It is possible the difference is attributable to the calibration solution used by each laboratory. ORNL values were referenced to the alpha and gamma isomers of chlordane, whereas TVA values were references to the nine individual congeners of chlordane.

REFERENCE

ORNL. 1990. "Fourth Annual Report on the ORNL Biological Monitoring and Abatement Program." Martin Marietta, Oak Ridge National Laboratory, Environmental Sciences Division. J. M. Loar, Editor. ORNL/TM Draft, April 1990.

Table A-1. Interlaboratory Quality Assurance--Knoxville-Area PCB Study (Suggested Comparison Format)

Number	I.D. code/number	Originating laboratory	Clinch River mile	Type of sample	Type of fish
1	89/02221	TVA-ECHE	2.0	individual	channel catfish
2	89/02223	TVA-ECHE	2.0	individual	channel catfish
3	89/02209	TVA-ECHE	2.0	composite	sauger
4		ORNL-ESD	19.0	individual	channel catfish
5		ORNL-ESD	19.0	individual	channel catfish
6		ORNL-ESD	24.0	individual	channel catfish
7		TN-LS	39.0	individual	channel catfish
8		TN-LS	39.0	composite	largemouth bass
9		TN-LS	50.0	individual	channel catfish
10		TN-LS	50.0	composite	largemouth bass

Table A-2. Interlaboratory QC Effort--Clinch River Fish Tissue, CRM 2.0 (TVA-Environmental Chemistry)

Laboratory Sample No.	Location/ type tissue	Laboratory	Chlordane[a] (mg/kg)	TPCB (mg/kg)	Percent lipids
	CRM 2.0/				
89/02209	sauger	ECHE-1	0.07	1.7	3.9
89/07738	comp 1-5	ECHE-2[b]	0.02	1.1	4.8
		State-TN[c]			
		ORNL	<0.03	0.50	4.27
	CRM 2.0/				
89/02221	CC 4A	ECHE-1	<0.02	<0.1	<0.1
89/06622		ECHE-2[b]	0.02	0.5	1.6
		State-TN[c]			
		ORNL	<0.02	0.10	0.44
	CRM 2.0/				
89/02223	CC 6A	ECHE-1	0.25	1.3	5.6
89/07735		ECHE-2[b]	0.02	1.0	3.8
		State-TN[c]			
		ORNL	0.10	1.42	5.76

a. Chlordane congeners were added and rounded according to the convention detailed in section 7.4.2 of Referee Method for the Mid-American Fish Contaminants Group. Only congeners that are present at >0.02 mg/kg are added to provide a "total" chlordane value.

b. A second aliquot of tissue reanalyzed in September 1989.

c. Due to technical problems, data are not available from the State Environmental Laboratory.

Table A-3. Interlaboratory QC Effort--Clinch River Fish Tissue, CRM 19.0/24.0 (TVA-Environmental Chemistry)

Laboratory Sample No.	Location/ type tissue	Laboratory	Chlordane[a] (mg/kg)	TPCB (mg/kg)	Percent lipids
89/04211	CRM 19/ CC 3 (7243)	ECHE-1	0.42	3.7	4.9
		State-TN[b]			
		ORNL	0.11	2.82	6.31
89/04214	CRM 19/ CC 3 (7245)	ECHE-1	<0.02	<0.1	<0.1
		State-TN[b]			
		ORNL	<0.02	0.38	3.83
89/04215	CRM 24/ CC 3 (7284)	ECHE-1	0.20	1.6	10.0
		State-TN[b]			
		ORNL	<0.02	1.42	11.7

a. Chlordane congeners were added and rounded according to the convention detailed in section 7.4.2 of Referee Method for the Mid-American Fish Contaminants Group. Only congeners that are present at >0.02 mg/kg are added to provide a "total" chlordane value.

b. Due to technical problems, data are not available from the State Environmental Laboratory.

Table A-4. Interlaboratory QC Effort--Clinch River Fish Tissue, CRM 39.0/50.0 (TVA-Environmental Chemistry)

Laboratory Sample No.	Location/ type tissue	Laboratory	Chlordane[a] (mg/kg)	TPCB (mg/kg)	Percent lipids
89/04217	CRM 39 LMB 1-5	ECHE-1	0.09	0.7	2.3
		State-TN[b]			
		ORNL	<0.02	0.73	3.02
89/04218	CRM 39/ CC 8A	ECHE-1	0.37	2.0	12.0
		State-TN[b]			
		ORNL	<0.02	2.59	11.7
89/04221	CRM 50/ LMB 1-5	ECHE-1	<0.02	<0.1	1.6
		State-TN[b]			
		ORNL	<0.02	0.12	2.15
89/04222	CRM 50/ CC 5A	ECHE-1	0.30	2.2	9.5
		State-TN[b]			
		ORNL	<0.02	c	c

a. Chlordane congeners were added and rounded according to the convention detailed in section 7.4.2 of Referee Method for the Mid-American Fish Contaminants Group. Only congeners that are present at >0.02 mg/kg are added to provide a "total" chlordane value.

b. Due to technical problems, data are not available from the State Environmental Laboratory.

c. Broken/lost in laboratory.

APPENDIX B

DETAILED INFORMATION ON PHYSICAL CHARACTERISTICS, LIPID CONTENT, AND PCB CONCENTRATION FOR EACH FISH COLLECTED FROM FORT LOUDOUN, TELLICO, WATTS BAR, AND MELTON HILL RESERVOIRS 1987, 1988, AND 1989

River mile	Date	Species[a]	Sex	Length (mm)	Weight (g)	Lipid (%)	PCB µg/g
		FORT LOUDOUN RESERVOIR					
LRM 3.0	88/10/26	LMB	F	535	2941	3.5	4.2
	88/10/26	LMB	M	469	1772	3.7	4.8
	88/10/26	LMB	M	447	1425	2.4	3.0
	88/10/26	LMB	M	416	1225	2.8	1.4
	88/10/26	LMB	M	315	423	0.9	0.8
	88/10/26	LMB	M	316	441	0.2	0.2
	88/10/26	LMB	M	320	441	0.4	0.4
	88/10/26	LMB	F	379	845	1.2	0.8
	88/10/26	LMB	F	434	1272	1.3	0.8
	88/10/26	LMB	F	311	391	0.6	0.3
	88/12/14	CHC	F	420	745	7.9	2.5
	88/12/14	CHC	M	496	1054	7.2	1.8
	88/12/14	CHC	M	436	876	4.0	4.2
	89/01/10	CHC	F	503	1558	8.5	5.4
	89/01/10	CHC	F	554	2105	6.9	3.8
	89/01/10	CHC	F	462	981	6.9	1.9
	89/01/10	CHC	F	523	1531	4.2	7.1
	89/01/10	CHC	F	507	1262	2.0	3.6
	89/01/10	CHC	M	466	1068	3.2	2.3
	89/01/10	CHC	M	606	2493	4.2	2.6
TRM 628.0	88/10/26	LMB	F	480	2011	0.7	0.3
	88/10/26	LMB	M	367	886	1.0	0.1
	88/10/26	LMB	F	473	2054	2.4	1.0
	88/10/26	LMB	F	361	877	1.9	0.4
	88/10/26	LMB	F	402	1031	1.4	0.4
	88/10/26	LMB	M	358	944	1.5	0.4
	88/10/26	LMB	M	465	1537	1.4	0.9
	88/10/26	LMB	M	385	1014	1.5	0.5
	88/10/26	LMB	M	372	879	1.1	0.3
	88/10/26	LMB	M	368	832	1.5	0.3
	88/10/26	CHC	F	540	1409	0.8	0.8
	88/10/26	CHC	F	417	618	3.7	0.7
	89/01/17	CHC	M	391	538	2.8	1.1
	89/01/17	CHC	F	434	742	11.0	1.0
	89/01/27	CHC	M	577	1732	1.9	1.1
	89/01/27	CHC	F	515	1345	9.3	0.2
	89/01/27	CHC	F	458	966	7.2	4.4
	89/01/27	CHC	F	447	795	5.4	0.3
	89/01/27	CHC	M	420	741	3.4	1.1
	89/01/27	CHC	F	457	796	8.3	1.0

River mile	Date	Species[a]	Sex	Length (mm)	Weight (g)	Lipid (%)	PCB µg/g
			TELLICO RESERVOIR				
LTRM 1.0	89/01/19	WE	M	490	1238	2.2	0.3
	89/01/19	WE	M	503	1233	2.0	0.2
	89/01/19	CHC	M	455	864	4.7	1.5
	89/01/20	CHC	M	510	1438	9.2	4.2
	89/01/20	CHC	F	396	552	5.4	0.7
	89/01/25	CHC	M	434	598	5.8	0.9
	89/01/25	CHC	F	432	641	5.3	3.3
	89/01/25	CHC	M	412	641	7.2	2.0
	89/01/25	CHC	F	431	788	4.8	0.9
	89/01/27	CHC	M	430	1037	0.4	0.3
	89/01/31	CHC	M	569	1881	2.9	0.4
	89/01/31	CHC	M	611	2481	3.9	1.9
LTRM 11.0	89/02/03	CHC	M	545	1470	1.0	1.3
	89/02/03	CHC	F	453	667	2.5	0.9
	89/02/03	CHC	M	473	947	1.3	0.9
	89/02/03	CHC	F	517	1456	0.9	0.9
	89/02/08	CHC	F	573	2610	8.7	2.0
	89/02/08	CHC	M	587	1744	2.6	2.2
	89/02/08	CHC	M	627	1756	0.2	0.9
	89/02/08	CHC	F	437	1068	2.6	1.0
	89/02/08	CHC	F	484	1030	5.6	0.7
	89/02/08	CHC	M	390	570	2.8	1.4
			WATTS BAR RESERVOIR				
TRM 532.1	88/12/13	BKS	F	350	660	1.5	<0.1
	88/12/13	BKS	M	293	411		
	88/12/13	BKS	F	321	550		
	88/12/13	BKS	M	293	407		
	88/12/13	BKS	F	276	345		
	88/12/13	LMB	M	415	1012	0.9	0.1
	88/12/13	LMB	M	343	577		
	88/12/13	LMB	M	398	896		
	88/12/13	LMB	F	350	573		
	88/12/13	LMB	F	345	527		
	88/12/13	CHC	M	460	796	3.3	1.6
	88/12/15	CHC	F	538	1875	6.7	2.1
	88/12/15	CHC	M	579	1923	6.7	2.5
	88/12/15	CHC	M	706	4210	16.0	4.3
	88/12/15	CHC	M	635	2654	0.9	0.6
	88/12/15	CHC	F	660	3524	6.7	2.5

River mile	Date	Species[a]	Sex	Length (mm)	Weight (g)	Lipid (%)	PCB µg/g
			WATTS BAR RESERVOIR (Continued)				
TRM 532.1	88/12/15	CHC	F	470	891	0.7	<0.1
(Cont.)	88/12/15	CHC	M	405	539	0.8	<0.1
	88/12/15	CHC	U	460	725	2.8	0.2
	88/12/15	CHC	U	398	494	0.9	<0.1
	88/12/16	STB	M	798	6626	11.0	4.4
	88/12/16	STB	M	570	2335	10.0	1.9
	88/12/16	STB	M	420	1005	7.9	0.2
	88/12/16	STB	M	534	2106	12.0	1.6
	88/12/16	STB	F	677	4000	14.0	2.0
	88/12/16	STB	M	590	2813	14.0	1.9
	88/12/16	STB	F	610	2742	10.0	1.6
	88/12/16	STB	M	795	7135	11.0	4.8
	88/12/16	STB	M	580	2594	11.0	1.6
	88/12/16	STB	M	420	905	7.1	0.2
	88/12/16	SBU	M	580	3280	12.0	0.4
TRM 561.9	88/11/23	CHC	F	657	2765	13.0	7.5
	88/11/23	CHC	M	618	2089	0.9	2.2
	88/11/23	CHC	F	456	788	6.0	2.0
	88/11/23	CHC	F	416	559	6.6	2.7
	88/11/23	CHC	M	390	411	5.8	1.3
	88/12/07	CHC	M	470	926	2.6	1.3
	88/12/07	CHC	F	555	1378	5.7	4.2
	88/12/07	CHC	F	434	669	8.3	1.9
	88/12/07	CHC	F	415	631	4.4	2.0
	88/12/07	CHC	F	512	1027	1.4	1.7
TRM 570	88/10/18	CHC	M	380	366	2.4	0.4
	88/10/18	CHC	F	429	668	3.0	1.4
	88/10/18	CHC	M	615	2425	4.5	3.7
	88/10/18	CHC	F	414	598	4.2	7.4
	88/10/18	CHC	M	346	264	0.7	0.1
	88/10/19	CHC	M	431	638	0.2	0.4
	88/10/19	CHC	F	578	2072	3.3	2.0
	88/10/19	CHC	M	526	1185	3.1	0.9
	88/10/19	CHC	F	398	610	7.5	2.6
	88/10/19	CHC	F	387	467	7.6	1.6
	88/10/19	SBU	M	496	2158	12.0	0.6
	88/10/19	SBU	M	480	1875	14.0	0.7
	88/10/19	SBU	M	481	1959	9.2	0.5
	88/10/19	SBU	M	537	2933	19.0	0.6
	88/10/19	SBU	F	533	3077	18.0	1.1
	88/10/19	SBU	M	504	1979	12.0	1.4

River mile	Date	Species[a]	Sex	Length (mm)	Weight (g)	Lipid (%)	PCB µg/g
			WATTS BAR RESERVOIR (Continued)				
TRM 570	88/10/19	SBU	M	530	2593	18.0	1.2
(Cont.)	88/10/19	SBU	M	480	1750	10.0	0.2
	88/10/19	SBU	M	484	1895	14.0	1.4
	88/10/19	SBU	M	522	2670	20.0	0.3
	88/10/20	LMB	M	512	2474	1.6	0.6
	88/10/20	LMB	M	440	1404		
	88/10/20	LMB	M	390	1010		
	88/10/20	LMB	M	361	688		
	88/10/20	LMB	M	369	722		
	88/10/20	WHS	F	320	472	0.6	0.1
	88/10/20	WHS	M	290	379		
	88/10/20	WHS	M	272	333		
	88/10/20	WHS	M	260	272		
	88/10/20	WHS	F	235	222		
TRM 600	89/01/11	CHC	F	491	1294	6.2	3.4
	89/01/11	CHC	M	468	829	3.6	1.3
	89/01/11	CHC	M	488	1131	6.2	3.3
	89/01/11	CHC	M	475	1058	6.6	1.0
	89/01/11	CHC	M	575	1639	2.1	0.8
	89/01/11	CHC	F	480	1094	6.3	4.0
	89/01/11	CHC	M	452	873	4.1	1.8
	89/01/11	CHC	M	659	2957	8.5	2.5
	89/01/11	CHC	M	463	897	5.2	1.1
	89/01/11	CHC	M	490	1119	3.5	4.4
	89/01/11	LMB	F	381	939	1.2	0.5
	89/01/11	LMB	M	452	1765		
	89/01/11	LMB	F	575	3326		
	89/01/11	LMB	M	422	1208		
	89/01/11	LMB	M	465	1788		
			CLINCH RIVER				
CRM 2.1	88/12/21	SAG	F	548	1615	3.9	1.7
	88/12/21	SAG	F	546	1971		
	88/12/21	SAG	F	526	1573		
	88/12/21	SAG	F	518	1626		
	88/12/21	SAG	F	547	1630		
	88/12/21	CHC	F	571	2023	7.9	4.0
	88/12/21	CHC	F	605	2262	7.0	4.6

River mile	Date	Species[a]	Sex	Length (mm)	Weight (g)	Lipid (%)	PCB µg/g
		CLINCH RIVER (Continued)					
CRM 2.1	88/12/21	CHC	M	547	1387	11.0	0.9
(Cont.)	88/12/21	CHC	F	484	784	<0.1	<0.1
	89/01/23	LMB	F	462	1512	2.3	0.6
	89/01/23	LMB	M	494	2241		
	89/01/23	LMB	F	516	2476		
	89/01/23	LMB	F	370	709		
	89/01/23	LMB	M	368	727		
	89/02/24	CHC	M	440	745	5.0	0.6
	89/02/24	CHC	M	541	1267	4.6	1.3
	89/02/24	CHC	M	454	863	7.5	2.4
	89/02/24	CHC	M	435	895	4.2	3.4
CRM 19	88/07/28	CHC	M	378	432	2.7	0.7
	88/07/28	CHC	F	363	391	4.4	0.3
	88/07/28	CHC	M	380	474	2.2	0.2
	88/07/28	CHC	F	495	1242	5.7	2.4
	88/07/28	CHC	M	407	622	3.5	0.3
	88/07/28	CHC	M	499	927	3.5	0.2
	88/07/28	CHC	M	309	340	2.5	0.2
	88/07/28	CHC	M	422	849	3.4	0.2
		MELTON HILL RESERVOIR					
CRM 21.0	88/07/26	CHC	M	455	740	1.0	0.2
	88/07/26	CHC	M	700	4850	2.2	0.4
	88/09/01	CHC	F	370	406	2.0	0.1
	88/09/01	CHC	F	442	572	4.6	0.6
	88/09/01	CHC	M	530	1888	5.3	1.6
	88/09/02	CHC	F	448	637	4.8	0.4
	88/09/02	CHC	F	790	6118	11.5	1.1
	88/09/07	CHC	F	388	433	2.3	0.1
	88/09/07	CHC	F	470	788	1.7	0.3
	88/09/07	CHC	M	540	1306	2.3	0.3
CRM 39.0[b]	88/11/23	LMB	F	474	1489		
	88/11/23	LMB	F	417	998		
	88/11/23	LMB	F	377	749		
	88/11/23	LMB	M	342	553		
	88/11/23	LMB	F	366	625		
	88/12/02	CHC	F	645	3330		

River mile	Date	Species[a]	Sex	Length (mm)	Weight (g)	Lipid (%)	PCB µg/g
		MELTON HILL RESERVOIR (Continued)					
CRM 39.0[b] (Cont.)	88/12/02	CHC	M	670	3121		
	88/12/02	CHC	F	575	2008		
	88/12/02	CHC	F	582	2211		
	88/12/02	CHC	F	553	1748		
	88/12/02	CHC	M	620	2271		
	88/12/02	CHC	M	627	2441		
	88/12/02	CHC	M	690	3906		
CRM 49.9[b]	88/11/23	CHC	M	504	1038		
	88/11/23	CHC	M	462	1010		
	88/11/23	CHC	F	506	1394		
	88/11/23	CHC	M	591	1763		
	88/11/23	CHC	F	640	3470		
	88/11/23	CHC	M	546	1770		
	88/11/23	CHC	M	519	1303		
	88/11/23	CHC	M	483	1026		
	88/11/23	LMB	F	399	1151		
	88/11/23	LMB	M	393	982		
	88/11/23	LMB	F	373	776		
	88/11/23	LMB	M	336	569		
	88/11/23	LMB	F	354	599		

a. Species Abbreviations:

LMB = largemouth bass
CHC = channel catfish
WE = walleye
BKS = Black crappie
STB = striped bass
SBU = smallmouth buffalo
WHS = white crappie
SAG = sauger

c. Tissue information available for only one fish at each site due to technical problems in the laboratory; see pages 16 and 17 for further explanation and table A-4 (page 48) for PCB and lipid data.